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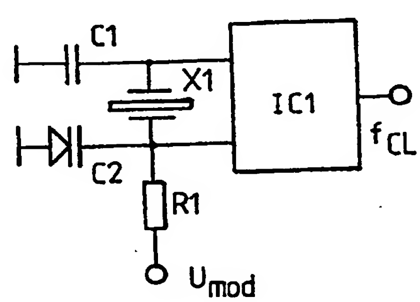
(54) A method and an arrangement for the attenuation of radiofrequency interferences caused by the harmonics of the clock frequency of digital devices.

(57) The invention relates to a method and an arrangement for the attenuation of radio-frequency interferences caused by the harmonics of the clock frequency of digital devices, such as a microprocessor. According to the invention, the spectrum of the harmonics of the clock frequency is treated by modulating (U_{mod}) the clock signal (f_{CL}).

FIG. 1



EP 0 416 423 A2

A METHOD AND AN ARRANGEMENT FOR THE ATTENUATION OF RADIO-FREQUENCY INTERFERENCES CAUSED BY THE HARMONICS OF THE CLOCK FREQUENCY OF DIGITAL DEVICES

The present invention relates to a method and an arrangement for the attenuation of radio-frequency interferences caused by the harmonics of the clock frequency of digital devices, such as microprocessors.

Microprocessors and other digital devices are today used widely in radio devices for performing various operations. In radio telephones, for instance, microprocessors are used particularly for the control of frequency adjustments and signalling. All the operations of the processor take place at a rate determined by a crystal oscillator, whereby high current peaks propagate at regular intervals in the signal lines of the device. These current peaks cause an interference spectrum in which some intense frequency components may fall at the receiving frequencies of the radio device, thus interfering with the signal coming from the radio path. This can usually be observed as an impairment in the sensitivity of the receiver or in the worst case as whistling occurring in the detected signal.

Several methods have been used in an attempt to attenuate interferences caused by the harmonics of the clock frequency of digital devices. For instance, the clock frequency has been decreased to reduce the rates of change of currents flowing in the circuit. This, however, has the drawback that the rate of performance of the computer decreases with decreasing clock frequency, so that the microprocessor is not capable of performing all required operations. In addition, when using standard microprocessors a re duction in the rate of change of signal currents requires additional components and increases the power demand of especially processors and memory circuits utilizing CMOS technique. These factors are both very important in portable mobile telephones in which lightness, small size and small power consumption are aimed at.

Another traditional way of compensating for interferences caused by the microprocessor is to place the interference emitting parts in an electromagnetically sealed encasing and to filter the signals coming to the outside of the encasing. An electromagnetically sealed encasing is, however, difficult as well as expensive to construct in a small space.

The object of th present invention is to provide a new method which reduces, in the receiver of a radio device, interferences caused by the harmonics of th clock frequency of microprocessors or other similar digital devices required in modern radio devices.

This object is achieved by means of a method of the type described in the preamble, which method is characterized in that the spectrum of the harmonics of the clock frequency is processed by modulating the clock signal.

The basic idea of the present invention is that interferences caused by the harmonics of the clock frequency are attenuated by spreading the power of sparsely distributed intense dot-frequency interference peaks over a wider frequency band around the original interference peak by modifying the interference spectrum in such a way that the interference energy is distributed more evenly over several radio channels with resultant decrease in the interference power acting on an individual radio channel.

The present invention provides a notable improvement in the attenuation of radio-frequency interferences caused by the microprocessors of radio telephones especially in connection with the electromagnetically sealed encapsulation used previously. Now the requirements set on the encapsulation are not, however, as severe as previously.

The invention is also concerned with an arrangement according to claim 6 for the attenuation of the interferences caused by the harmonics of the clock frequency.

In the following the invention will be described in greater detail by means of exemplifying embodiments with reference to the attached drawings, in which

Figure 1 shows a crystal oscillator in which the modulation of the invention is realized;

Figure 2 shows a block diagram of an arrangement of the invention in which a phase shift means is connected after a sinusoidal wave generator;

Figure 3 shows a block diagram of an arrangement of the invention in which a phase shift means is connected after a rectangular wave oscillator;

Figure 4 shows a pseudorandom modulation signal from one clock period; and

Figure 5 illustrates the spreading of interference energy in the frequency domain by means of the method and the arrangement of the invention.

Today the bandwidth of one radio channel in cellular telephon systems is, depending on the system, 12.5 to 30 kHz and the bandwidth of the filters of the receiver is som what narrower on account of the filtering requirement of a neighbouring channel. In Figure 5, the reference numeral 50 indicates one radio telephone channel in the frequency domain. The clock-frequency current

and/or voltag peaks propagating in the signal lin s of the microprocessor of the radio telephone may caus intense interference components that fall on individual frequencies. These interference components are the harmonics of the clock frequency (n x clock frequency). In Figure 5, the reference numeral 51 indicates an intense interference peak falling on the frequency band 50 of the radio channel.

According to the invention the energy of such a dotlike interference frequency can be spread over a wide frequency domain by modifying the clock frequency by modulating the clock signal.

Figure 1 shows a crystal oscillator circuit which can be modulated according to the invention. The crystal oscillator circuit comprises a conventional integrated oscillator circuit IC1 to which an oscillator circuit formed by a crystal X1 of a capacitor C1 and a capacitance diode C2 is connected. The oscillation frequency of the oscillator depends in a known manner on the properties of the crystal X1 as well as on the capacitance values of the capacitor C1 and the capacitance diode C2. In this particular case, the capacitance of the capacitance diode C2 is adjusted by a modulating voltage U_{mod} applied through a resistor R1 between the crystal X1 and the capacitance diode C2. The modulating signal and the type of modulation may be selected according to the requirements in each particular case.

The simplest way is to use frequency modulation (phase modulation) of the clock frequency in such a way that the spectrum of the harmonics of the clock frequency is spread over more than one radio channel. Even a very slight spreading of the spectrum attenuates a whistling-type interference but a more drastic spreading is needed to increase the sensitivity of the receiver. As is well-known, the spectrum of a frequency-modulated signal depends on the modulating signal and the frequency deviation (phase deviation) caused by the modulation.

In cases where the modulating signal U_{mod} is a sinusoidal signal, the modulated signal f_{CL} comprises dotlike frequency components at intervals of the modulation frequency f_{mod}, the relative magnitude of the frequency components with respect to the unmodulated carrier wave depending on the modulation index (phase deviation). Figure 5 illustrates the interference spectrum of a modulated clock frequency by means of an envelope 52. An advantageous interference spectrum is obtained by using a relatively small modulating frequency and a large frequency deviation. The frequency of the modulating signal is preferably e.g. about 1 to 5 kHz and the deviation at the interference frequencies e.g. 10 to 30 kHz.

The modulating signal U_{mod} need not necessarily be a sinusoidal signal. One of the most important alternatives is a pseudorandom word or signal, whereby the modulating signal has a random wave form. Especially when using digital techniqu , this kind of signal is advantageous in that it is easier to generate than a sinusoidal signal and the form of the spectrum is more advantageous in view of the interferences. When the spreading is performed by a sinusoidal modulating signal, the interference spectrum is emphasized in the vicinity of a frequency corresponding to the frequency deviation, which does not occur when using a pseudorandom signal. When the modulating signal and the length and bit duration of the pseudorandom word are selected suitably, the interference spectrum is similar to, e.g., a MSK (FFSK) signal at the receiving frequencies of the radio device. Figure 4 shows a pseudorandom modulating signal from one clock period.

Figure 2 shows an alternative arrangement for modulating the clock signal of a microprocessor. The arrangement comprises a sinusoidal clock signal generator 21 which generates the clock signal of the microprocessor. An adjustable phase shift means 22 is connected to the output of the clock generator 21, and a circuit 23 modifying the sinusoidal signal into rectangular clock pulses is connected to the output of the adjustable phase shift means 22. This gives a clock frequency f_{CL} to be applied to the microprocessor. The amount of phase shift caused by the phase shift means 22 is adjusted (modulated) by means of a modulating signal Umod applied to the adjusting input of the phase shift means 22. The modulating signal U_{mod} may be similar to that shown in Figure 1. The resulting signal is the clock signal f_{CL} modulated according to the invention.

Figure 3 shows a digital realization of Figure 2, in which an adjustable phase shift means 32 is connected to the output of a rectangular wave generator 31. The phase shift caused by the phase shift means 32 is adjusted by a modulating signal Umod applied to its adjusting input. In this case the clock generator 31 may generate a high-frequency signal having a frequency higher than the final clock frequency. The phase shift means 32 thereby acts, for instance, as a fraction divider the divisor of which varies with the modulating signal U_{mod}.

The effect of the modulation according to the invention on the clock signal can be described in the time domain in such a manner that the significant edges of the clock pulses (rising or falling edge controlling the logic) are displaced in the time domain continuously or in a stepwise manner within predetermined variation limits. It is also possible to modulate both edges of the clock pulses. In cases where the clock frequency of the processor is used for some other than the time critical purpose, for instance, as a reference in the frequency

synth sizer of a radio telephone, or to produce a carrier wave for a modem, it is, however, to be preferred to modulate only the significant edges of the clock pulses, whereby the other edges can be used for the above-mentioned purposes, which require a highly stable clock frequency.

The attached figures are only intended to illustrate the present invention. In their details, the method and the arrangement of the invention may vary within the attached claims.

Claims

1. A method of attenuating clock-frequency interferences caused by the harmonics of the clock frequency of digital devices, such as a microprocessor, **characterized** in that the spectrum of the harmonics of the clock frequency is processed by modulating the clock signal.
2. A method according to claim 1, **characterized** in that a clock oscillator is modulated directly.
3. A method according to claim 1, **characterized** in that the clock signal generated by the clock oscillator is modulated.
4. A method according to claim 1, 2 or 3, **characterized** in that the modulating signal is a continuous signal, such as a sinusoidal signal, or a signal having a pseudorandom waveform.
5. A method according to claim 1, 2, 3 or 4, **characterized** in that the front or the back edge or both of the clock pulse of the clock signal are displaced in the time domain by modulating.
6. An arrangement for attenuating interferences caused by the harmonics of the clock frequency of digital devices, such as a microprocessor, **characterized** in that it comprises means (C2, 22, 32) for modulating a clock signal.
7. An arrangement according to claim 6, **characterized** in that it comprises a crystal oscillator for generating a clock signal, a crystal (X1) in the crystal oscillator being connected to a serial or parallel resonance circuit in which at least one capacitive component is formed by a capacitance diode (C2) the capacitance of which is adjusted by a modulating signal (U_{mod}).
8. An arrangement according to claim 6, **characterized** in that it comprises a phase shift means (22, 32) connected in series with a clock signal source (21, 31), the phase shift caused by said phase shift means being modulated by the modulating signal (U_{mod}).
9. An arrangem nt according to claim 8, **characterized** in that the clock signal sourc (31) supplies a signal having a rectangular waveform, th phase shift means being formed by a digital divider circuit, preferably a fraction divider, the divisor of which varies with the modulating signal.
10. An arrangement according to any of the preceding claims, **characterized** in that the modulating signal (U_{mod}) is a continuous signal, such as a sinusoidal signal, or a signal having a pseudorandom waveform.
11. Use of an arrangement according to any of claims 6 to 10 in radio devices, particularly in radio telephones.

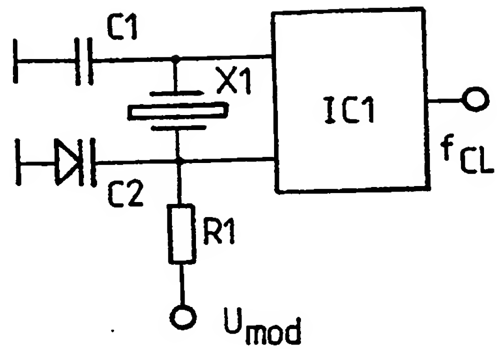


FIG. 1

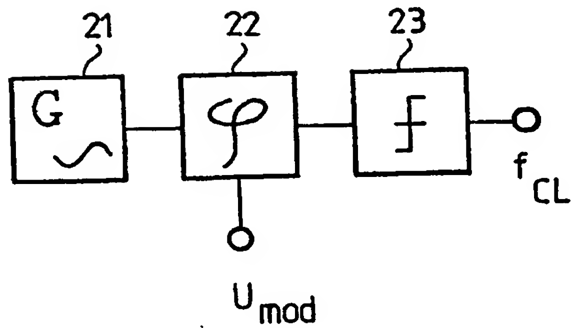


FIG. 2

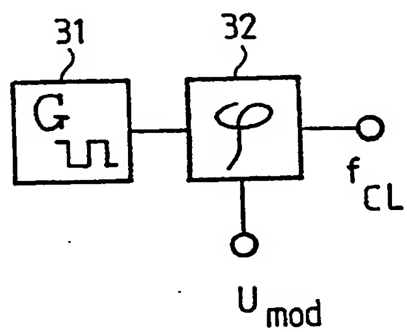


FIG. 3

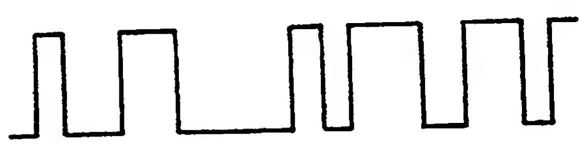


FIG. 4

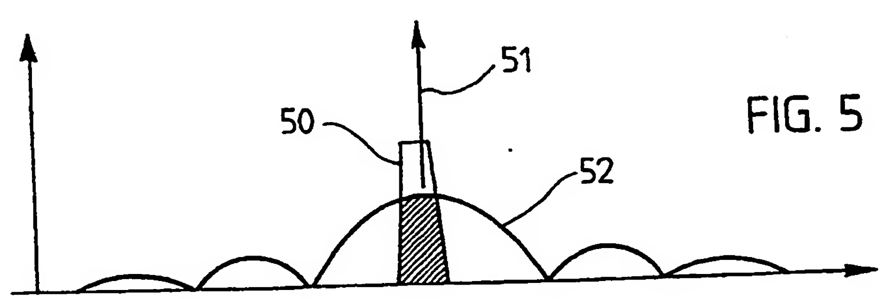


FIG. 5